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OVERVIEW OF LASER CONCEPTS

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Abstract

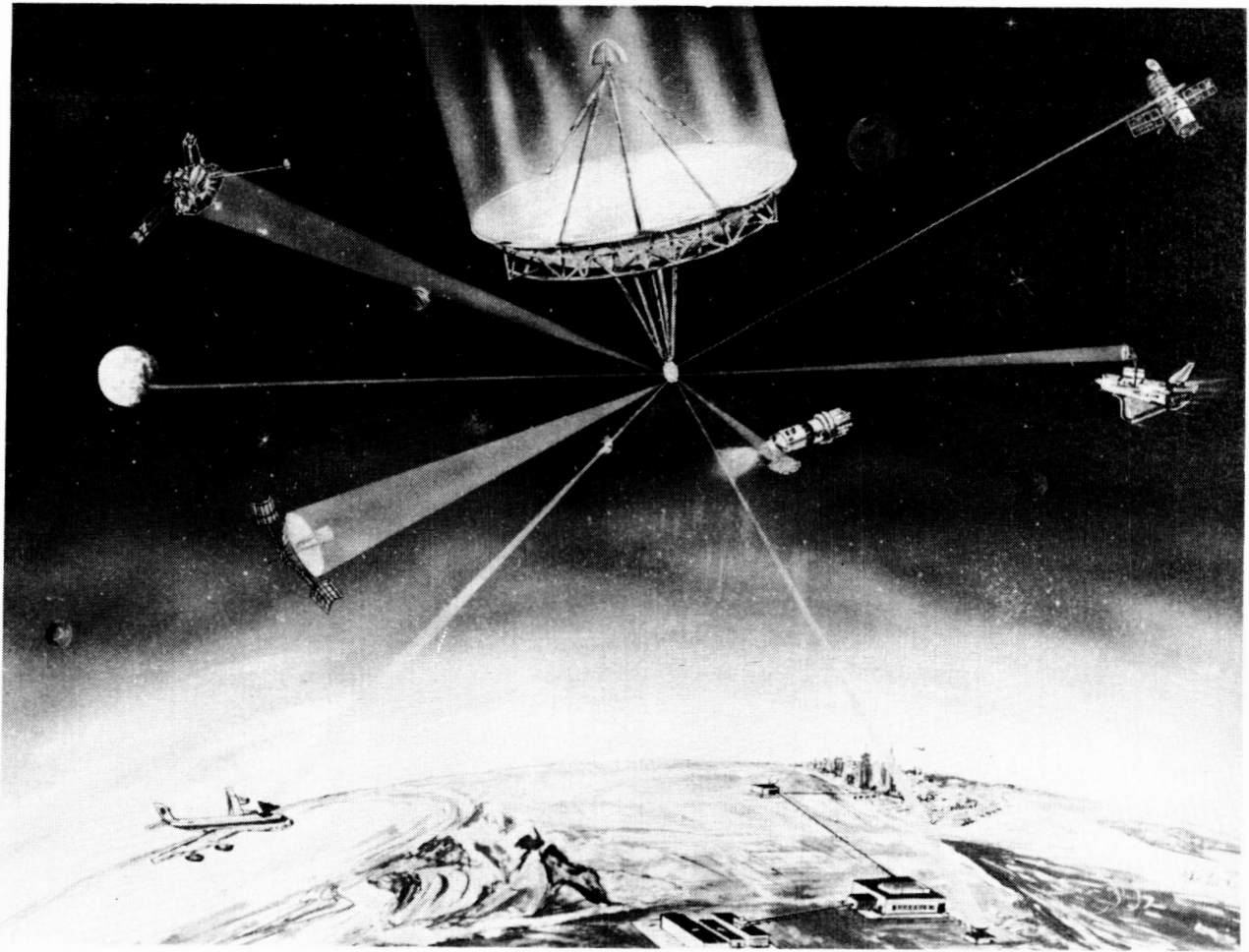
A number of laser-power transmission applications are overviewed. Some will be expanded in the miniworkshops to follow, and other applications mentioned here are given to provide some breadth to the potential use of laser-power transmission in space.

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SOLAR-PUMPED LASER APPLICATIONS

Space-laser power stations have been discussed for many years. This figure shows eight applications which have received some consideration. They range from terrestrial power to aerospace uses, such as spacecraft propulsion.



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APPROACH

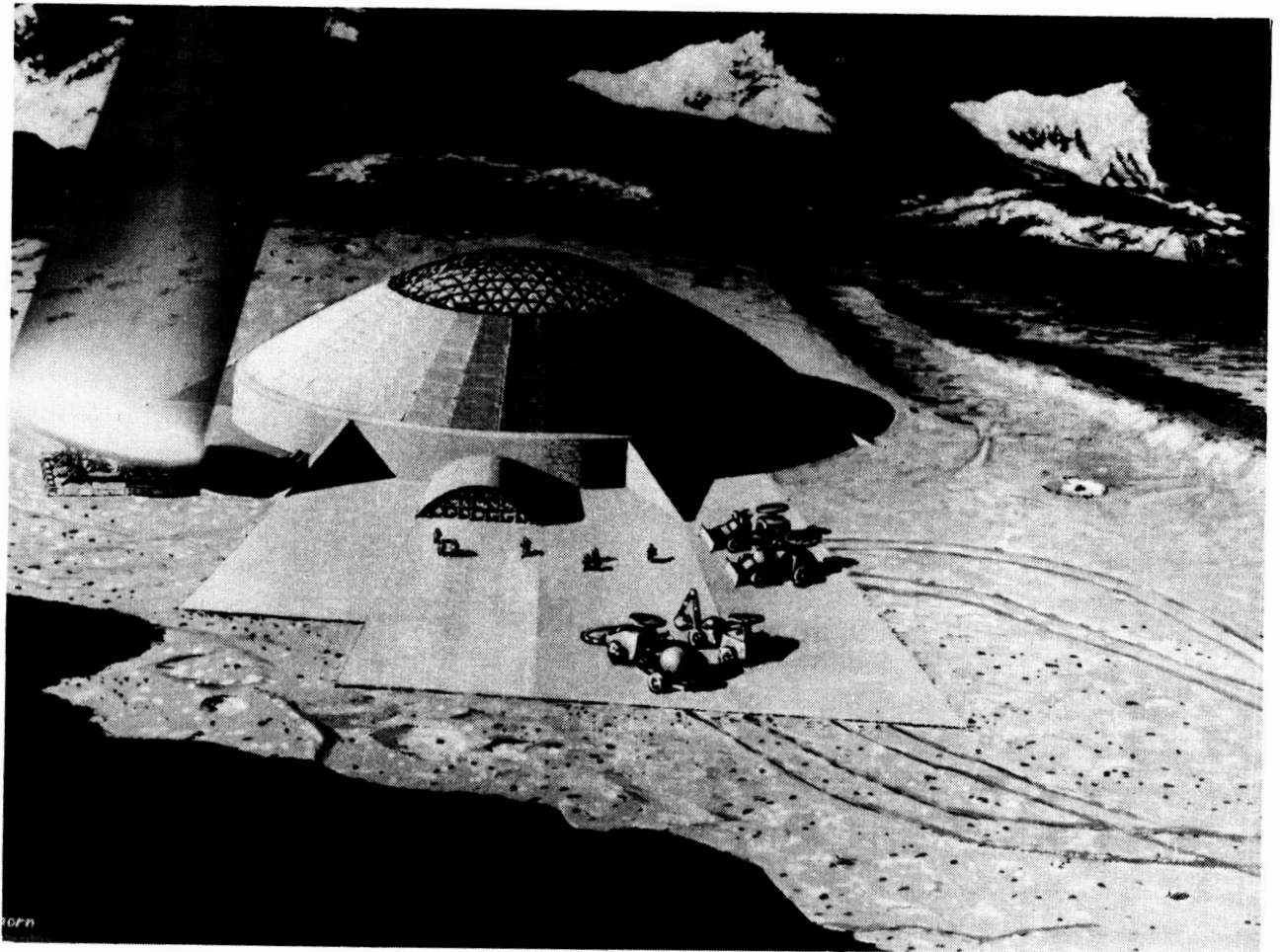
One of the purposes of this workshop is to identify beamed-power applications which offer a high payoff for NASA missions. These NASA missions are (1) lunar and planetary exploration, (2) transportation from Earth to the Moon or planet, and (3) near-Earth operations. Thus, the miniworkshop is broken up into three areas: planetary power, propulsion, and near-Earth applications. The approach to this overview is to identify a broad set of applications for laser planetary power, for laser propulsion, and for near-Earth uses. However, this overview will touch about equally on concepts to be presented at this workshop and on concepts which have been passed over. The overview will close with a discussion of the lasers that have been considered in this miniworkshop study.

LASERS FOR PLANETARY POWER

We will be reviewing in turn briefly power to a Mars base, Martian geophysical analysis, a Mars pipeline heater, lunar base power, and power for an advanced rover.

A MARS BASE

This figure shows an example of power to a base on Mars. A number of activities are in view around the base, but the primary element is the power arriving at this base from distant orbiting power station. The power is being collected by a fairly small laser-to-electric converter shown in the figure. Because a manned base on Mars is included in the studies of the Office of Exploration (Coze Z), this is a concept to be reviewed at this workshop.



GEOPHYSICAL ANALYSIS

This figure shows a remote geophysical analysis of Martian soil in progress. A number of spectrophotometers have landed, and they have their microwave antennae pointed toward the orbiting power station. The laser beam for the power station strikes the ground, producing a plasma which emits light. This light is spectrophotometrically analyzed by the nearby robot spectrophotometers to determine the elemental composition of the surface and to transmit the results to the power station. Since geophysics is not a primary agency interest, this concept was not prepared for the workshop.

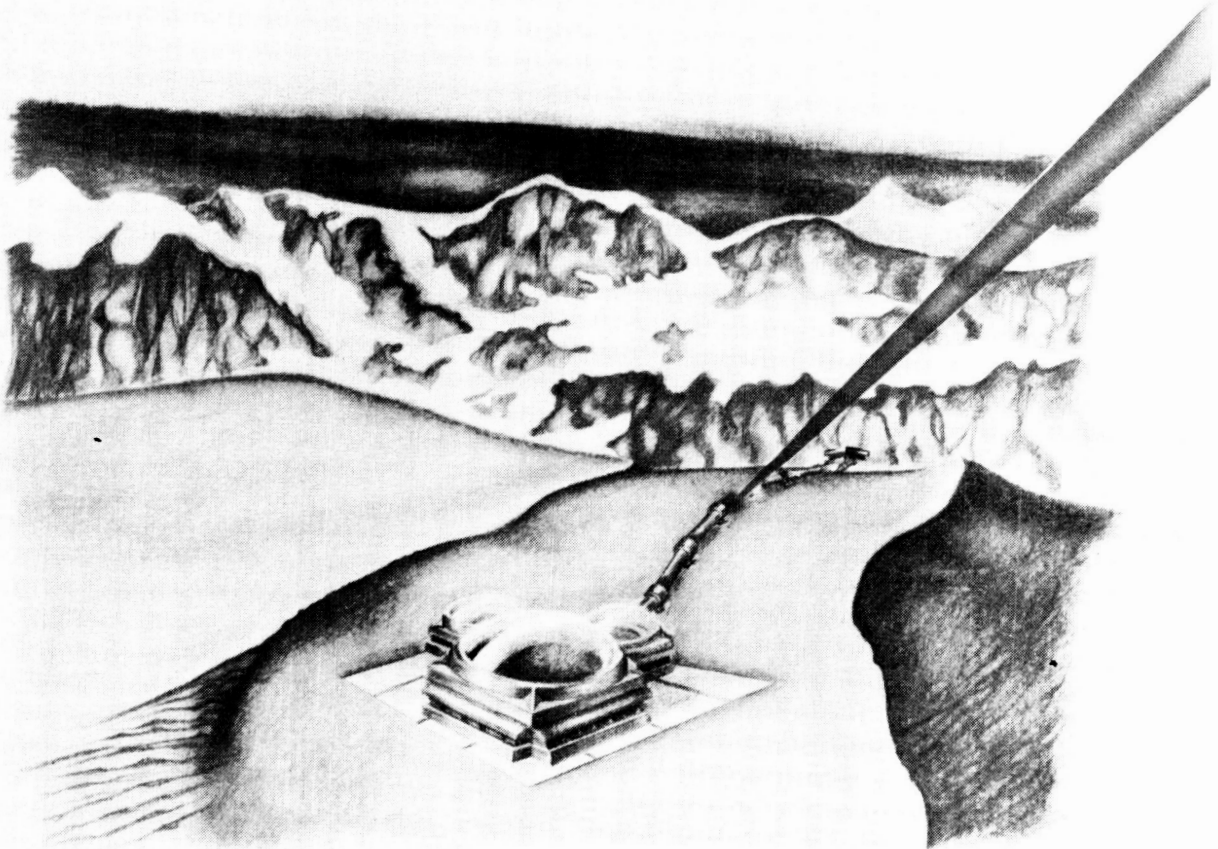


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THE MARS PIPELINE HEATER

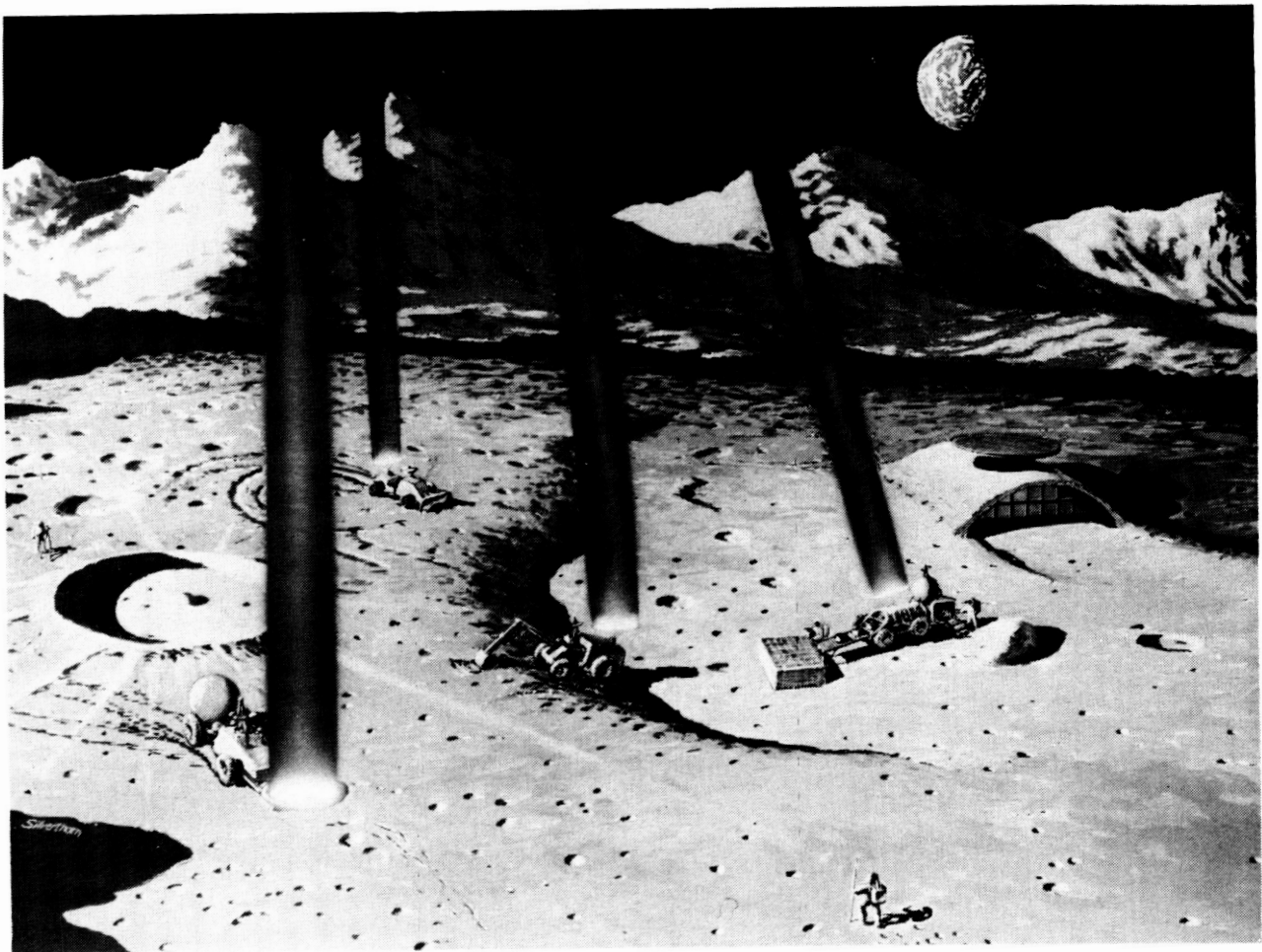
Manned landings on Mars are almost certain to be close to the equator of the planet for orbital mechanics reasons, yet later when a permanent presence on Mars is developed, people will need a variety of resources--among them--water. There is a good deal of water in the polar regions of Mars in the form of solid ice. The figure shows a laser heating a pipe in which liquid water is flowing, but the pipe must be kept warm to keep the water from freezing and the pipe from blocking. This is one application for laser power for advanced, permanently inhabited Mars bases. This application, beamed power providing water for a manned Mars base, is so far in the future that it is of little importance in 1989.

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A LUNAR OUTPOST

Here the setup is less permanent than those that were shown on Mars. This lunar outpost is far from the main base which might be either laser or fission powered. However, the outpost will be laser powered because it is a temporary base which must be picked up and moved every few months and cannot justify a permanent nuclear power system. This outpost supports prospecting in a particular area, so it is not quite as large-scale nor as permanent as in the Mars base concepts. Both lunar and Mars bases are included in our preparation on planetary power for the workshop.

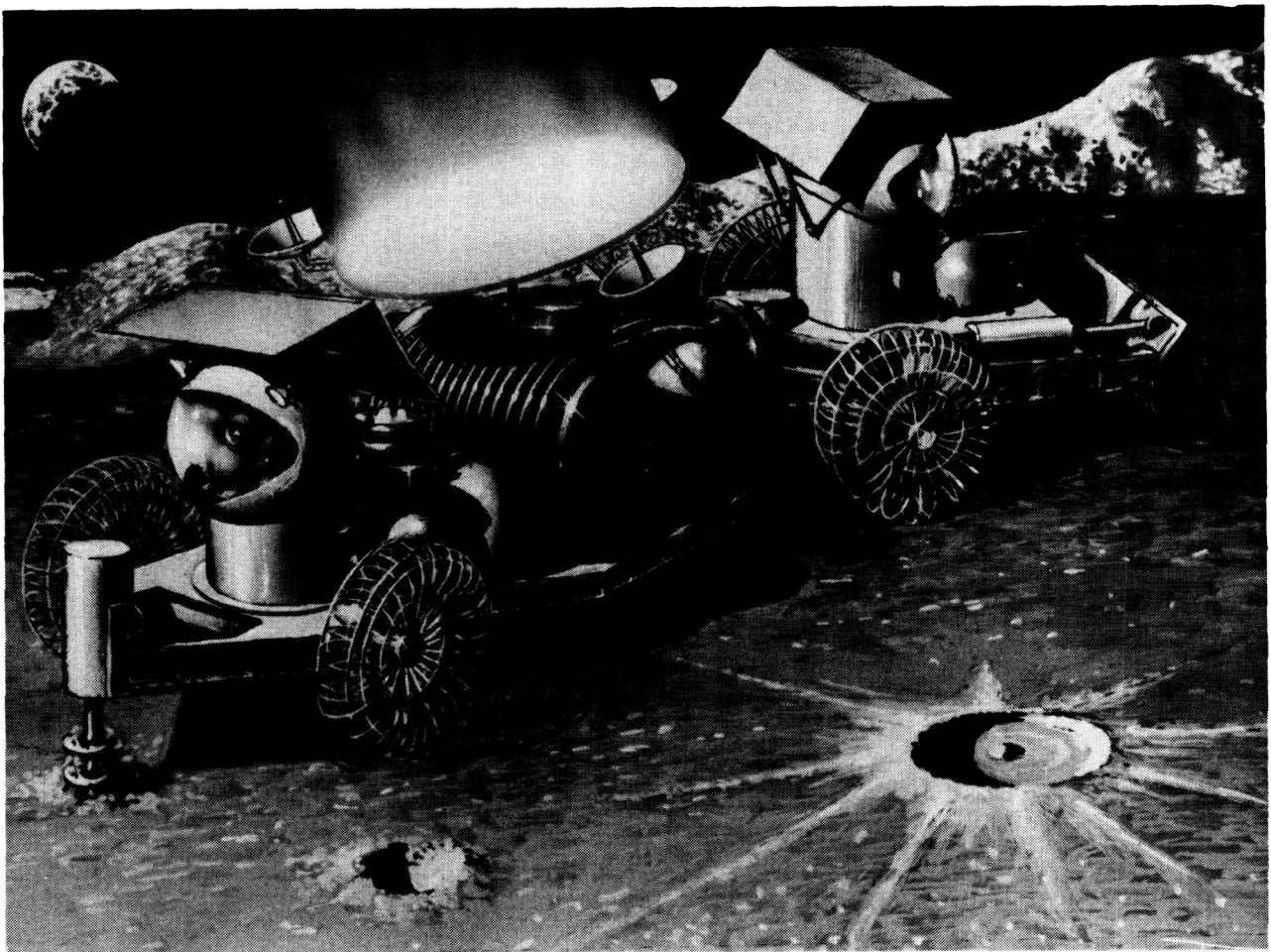


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AN ADVANCED ROVER

This figure shows the laser power beamed to an advanced rover, with the power being collected by a laser photovoltaic converter which is approximately two meters in diameter, smaller than the width of the rover itself. The rover has a capability of locomotion, of coring, of pushing soil, communications, chemical analyses, and a number of other uses. The power for all of this is provided by the laser beam. A beamed-power rover is part of our workshop preparation.



LASER PROPULSION

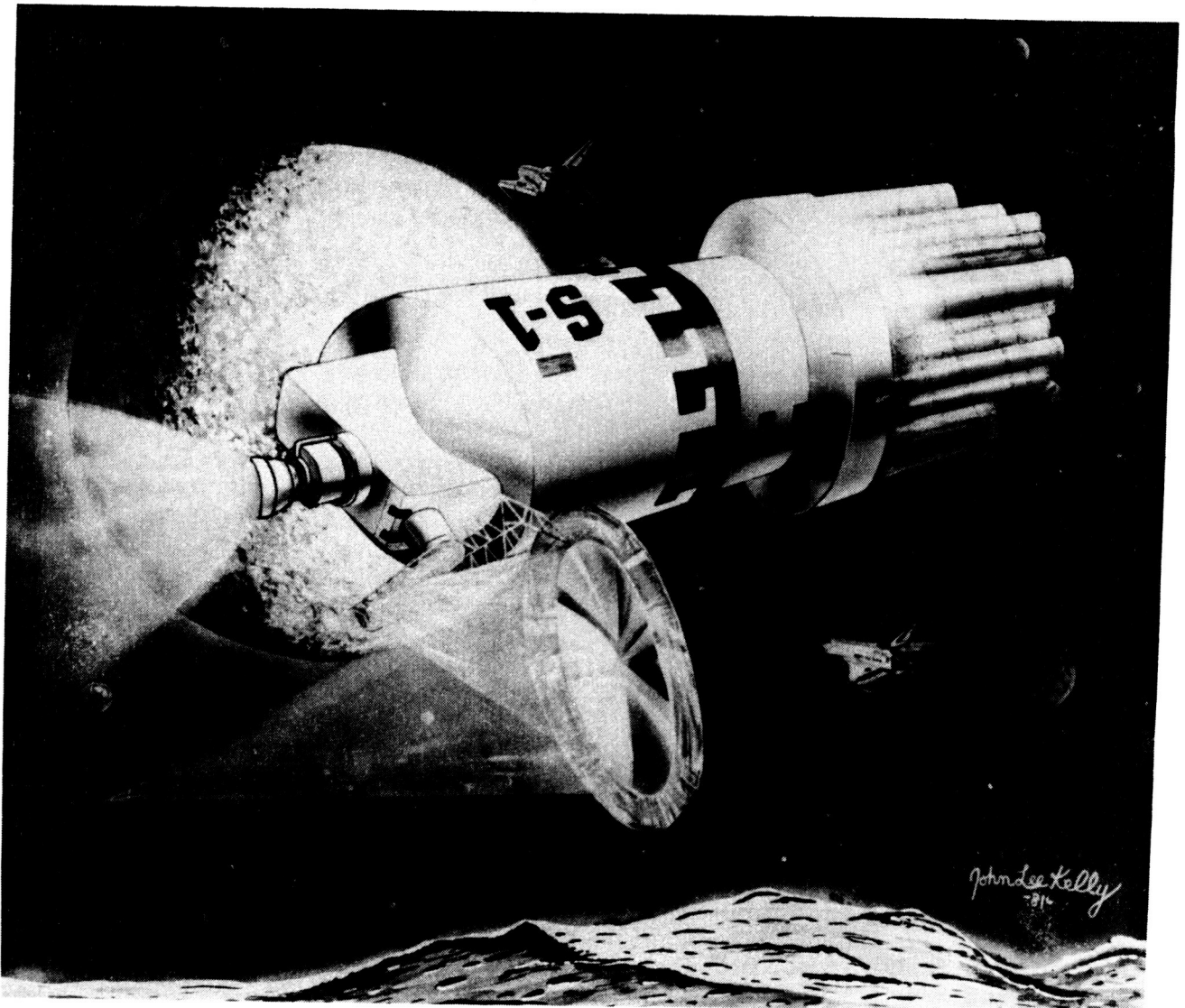
Let's change the topic from planetary exploration to how you travel from Earth to the neighborhood of a planet. Lasers have been considered for Earth-to-orbit propulsion and for propulsion involved in orbit raising. There has been consideration given to laser light sails, to laser electrical propulsion for low altitude satellites in high-drag orbits, and laser thermal propulsion for transfer from low-Earth orbit to low-lunar orbit. We will discuss these on the following figures.

LASER-SUPPORTED PURE HYDROGEN ROCKET

This is a concept for a laser thermal rocket in which the laser beam comes in through a focusing window or lens, heating gaseous hydrogen to a very high temperature, approximately 20,000° kelvin, and the hot gas escapes through a rocket nozzle, producing thrust. This particular concept was developed by Marshall Space Flight Center, and it is the engine for the propulsion concept which Langley is presenting in this workshop.

THE S-1 LASER OTV

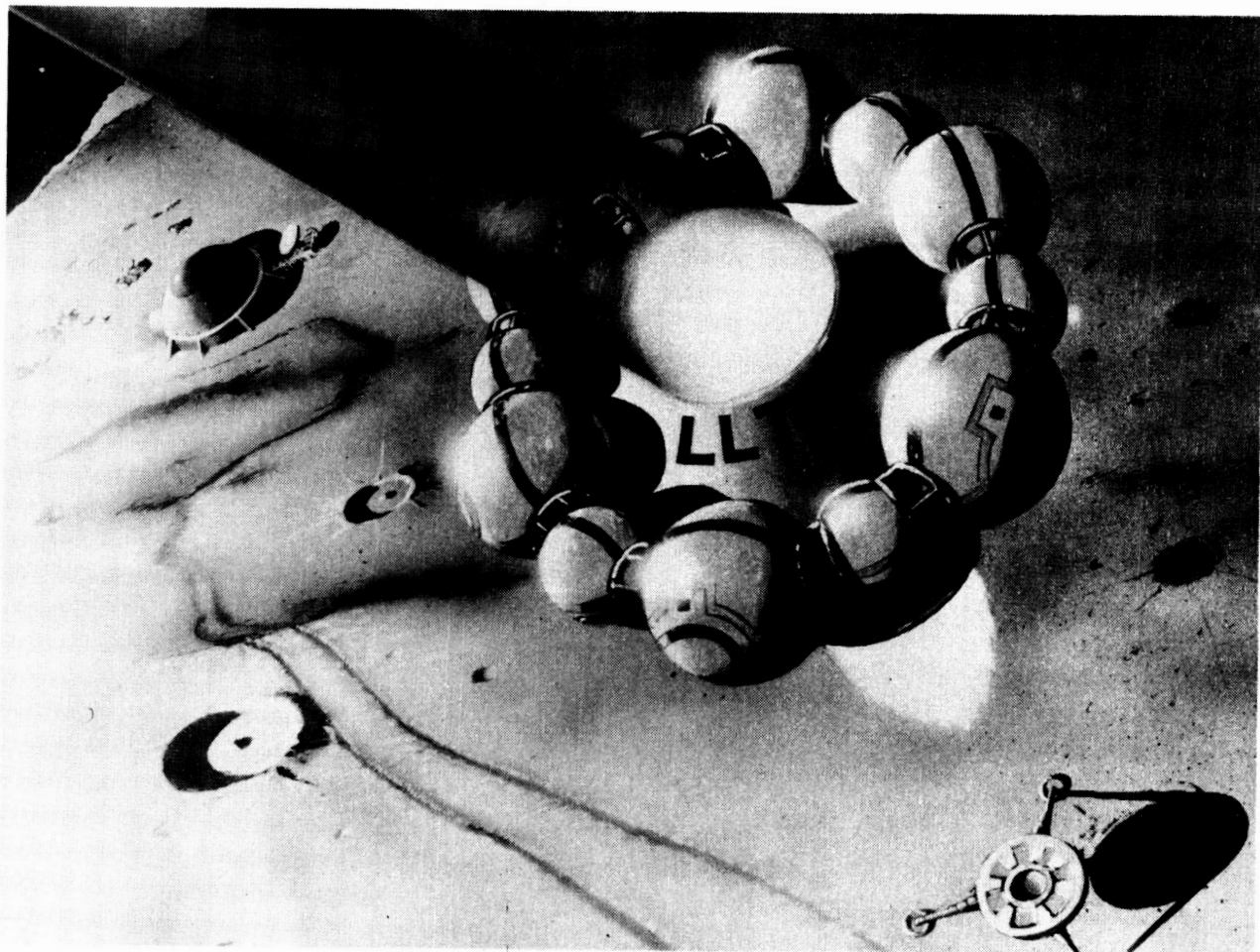
This is an artist's conception of a laser thermal orbit transfer vehicle. It shows the orbit transfer vehicle receiving power from a distant laser after it has been placed in orbit by the space shuttle. The cargo looks like tubes or pipes off to the right in the figure.



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LLTS./LUNAR LASER TRANSPORTATION SYSTEM

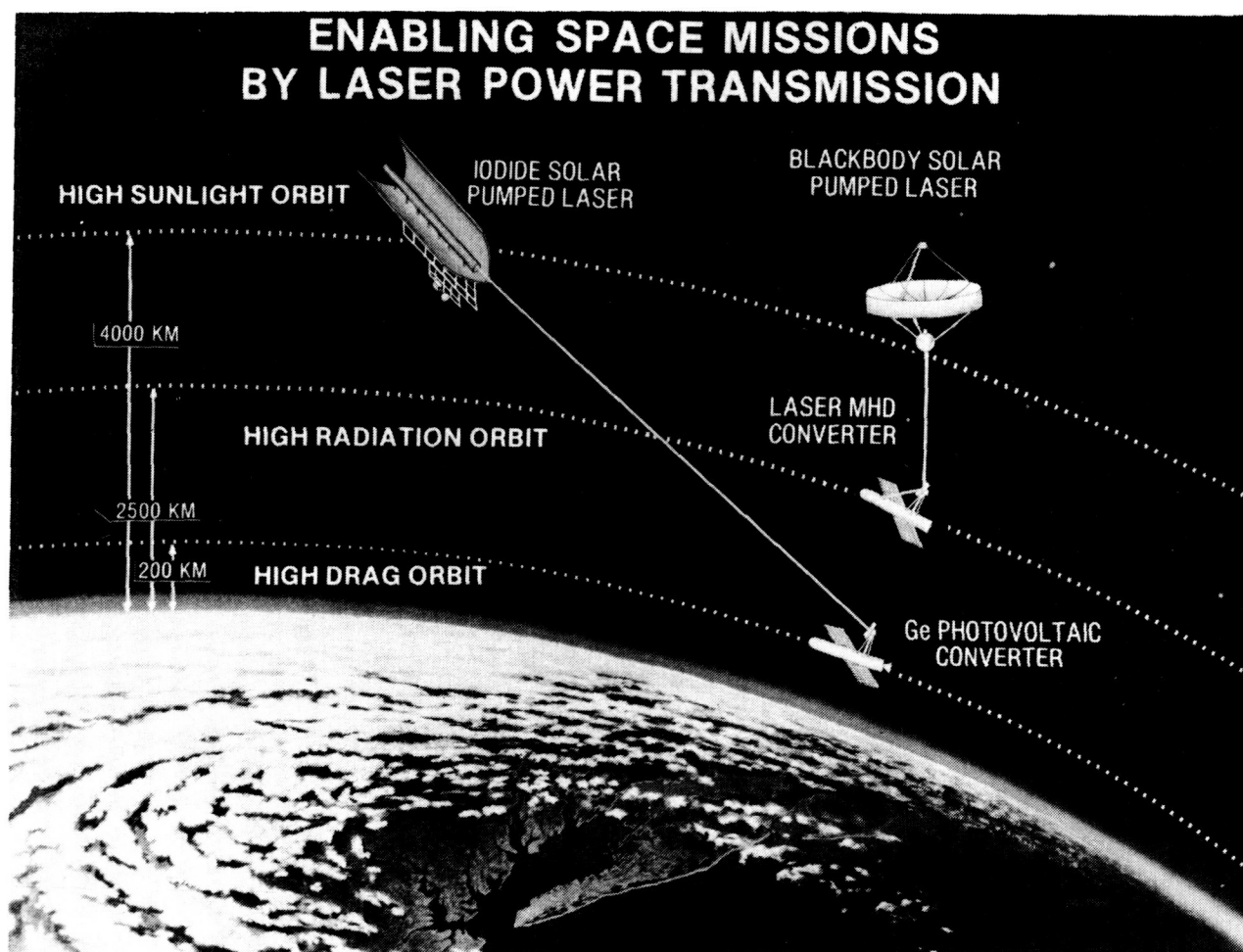
This figure is an artist's conception of a laser thermal rocket during liftoff from the surface of the Moon. The launch point is not far from a permanent lunar base which appears to the left in the figure. This is the concept for a transfer system from the lunar surface to low-lunar orbit. To complete the laser transportation catalog, shortly we will be talking about an orbit transfer vehicle from low-lunar orbit to low-Earth orbit. This LLTS system did not offer high enough value to NASA for presentation in this workshop.



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ENABLING SPACE MISSIONS BY LASER-POWER TRANSMISSION

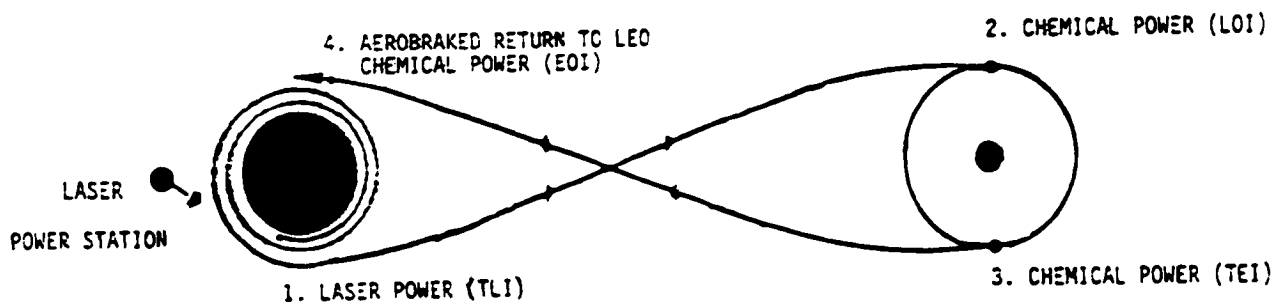
This figure shows two possible uses for lasers. In one case, a laser in high orbit transmits power to an electric propulsion system in a low-altitude, high-drag orbit. The small area for the laser-to-electric converter permits large amounts of power to be generated without much drag. (Large amounts of drag are associated with solar photovoltaic arrays which provide the same power level.) This system could remain in orbit at altitudes significantly lower than 200 kilometers for as long as the fuel would last. The other option in this figure is to use a blackbody laser, in high orbit to transmit power to a spacecraft in orbit that received a great deal of radiation. The critical subsystem is a radiation insensitive laser-to-electric converter, such as the MHD converter shown in this figure. Neither of these concepts offer as high a payoff to NASA and are not among the concepts which we have prepared for this workshop.



HYBRID LASER/CHEMICAL OTV

This figure shows the hybrid laser/chemical orbital transfer vehicle for low-earth orbit to low-lunar orbit operations. The interesting feature about this concept is that only one laser power station is required. The power station is in a high earth orbit, and it provides power only for acceleration to escape the earth's gravity-well. Small amounts of chemical power are used to circularize the orbit around the Moon and for thrust to begin the return from the Moon. An aerobrake is used to decelerate the spacecraft for Earth capture. There will be more presented on this concept in the propulsion session of the workshop.

FOR LEO-LLO OPERATIONS

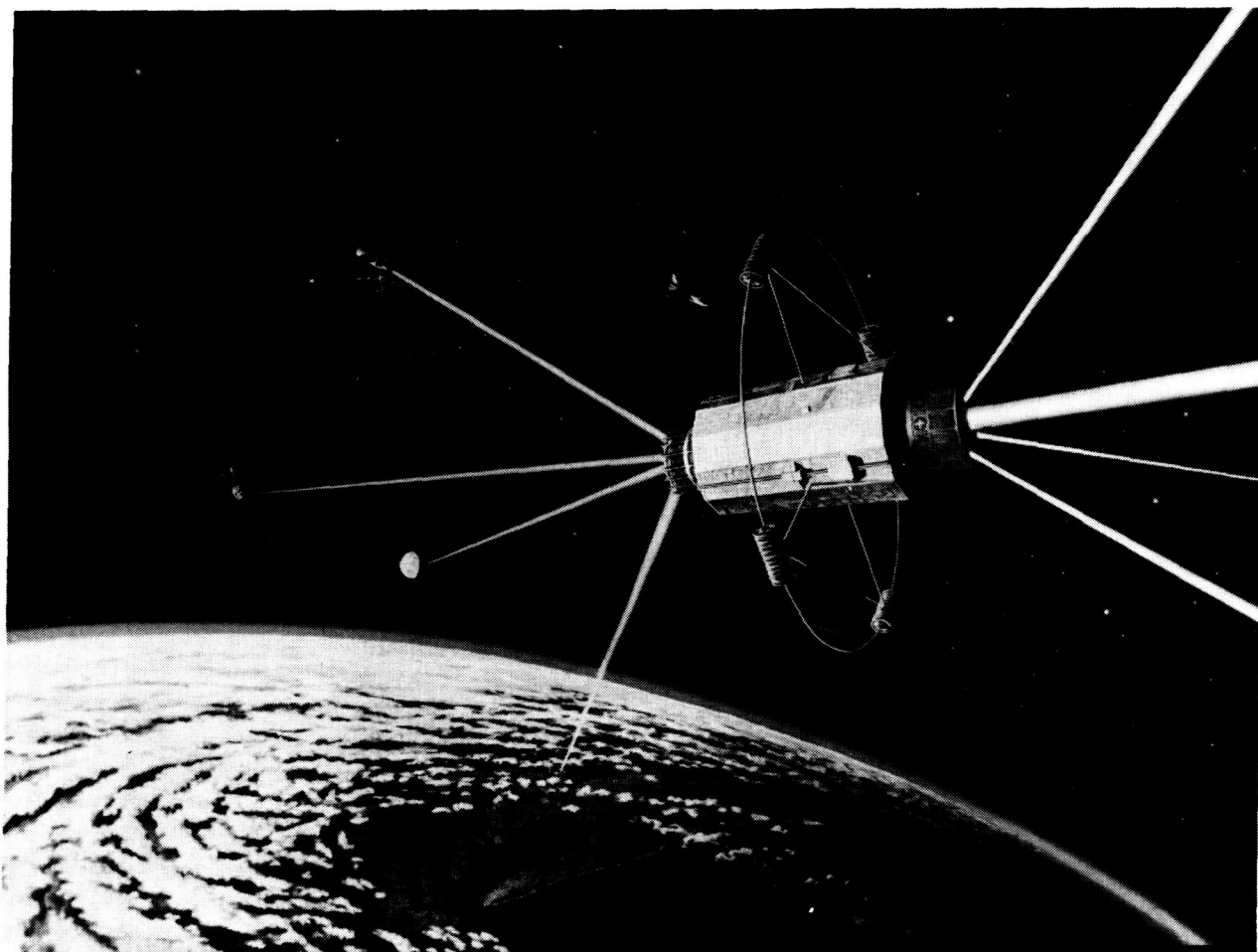


NEAR-EARTH APPLICATIONS OF LASER POWER

We will touch on four topics: (1) power transmitted from space to Earth, (2) power for a space industrial complex , (3) power for GEO satellites, and (4) power for Space Station Freedom.

NUCLEAR-PUMPED LASER PROVIDING POWER TO EARTH

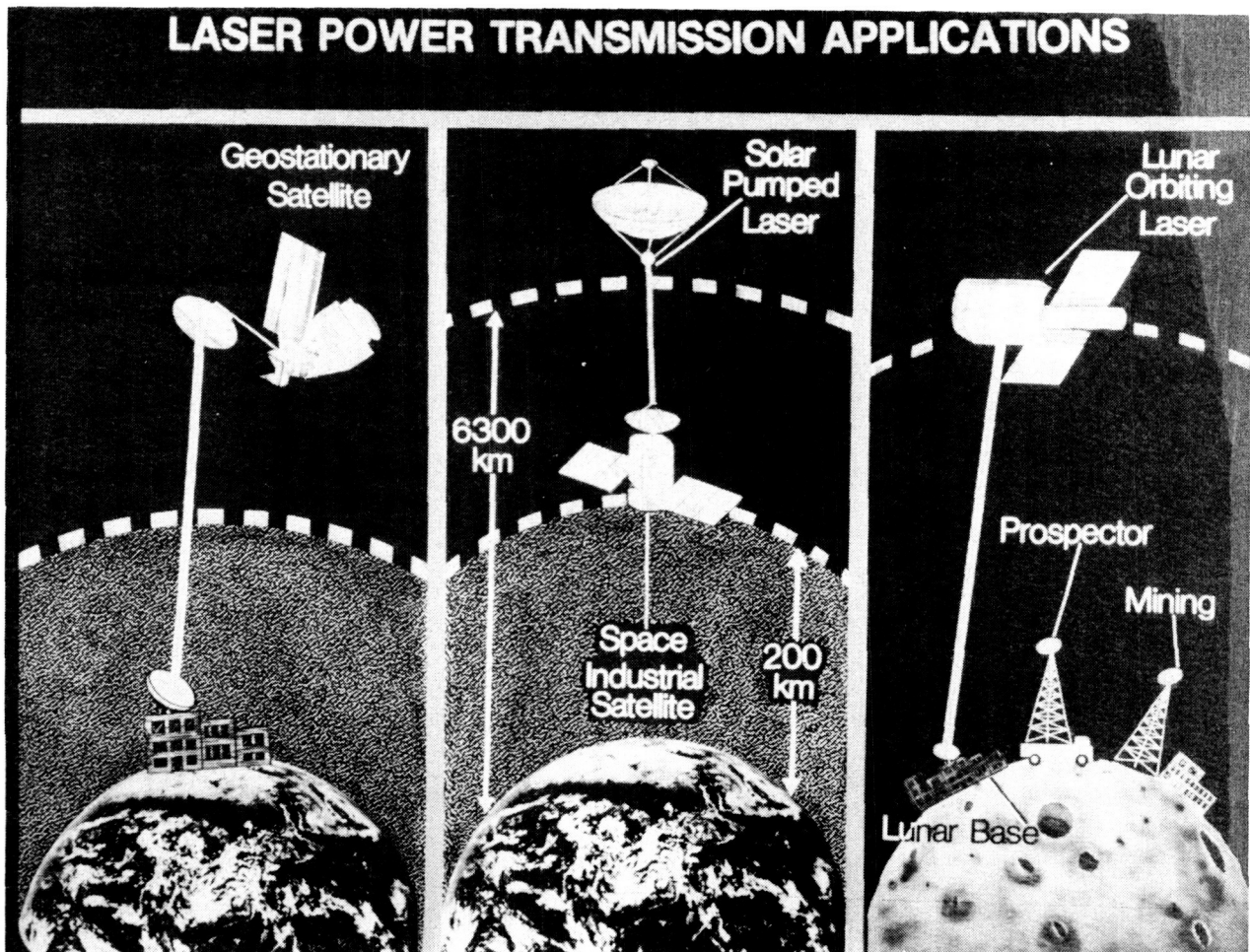
Here you see a nuclear-pumped laser providing power for four users and having several other beams emitted also. The beam of primary interest here is the one that goes to the ground. As you can see, this beam is directed to a large power station near some unidentified city, west of but near the northern end of the Chesapeake Bay on the East Coast of the United States. One can only wonder what city is important enough to receive the first power transmitted from space.



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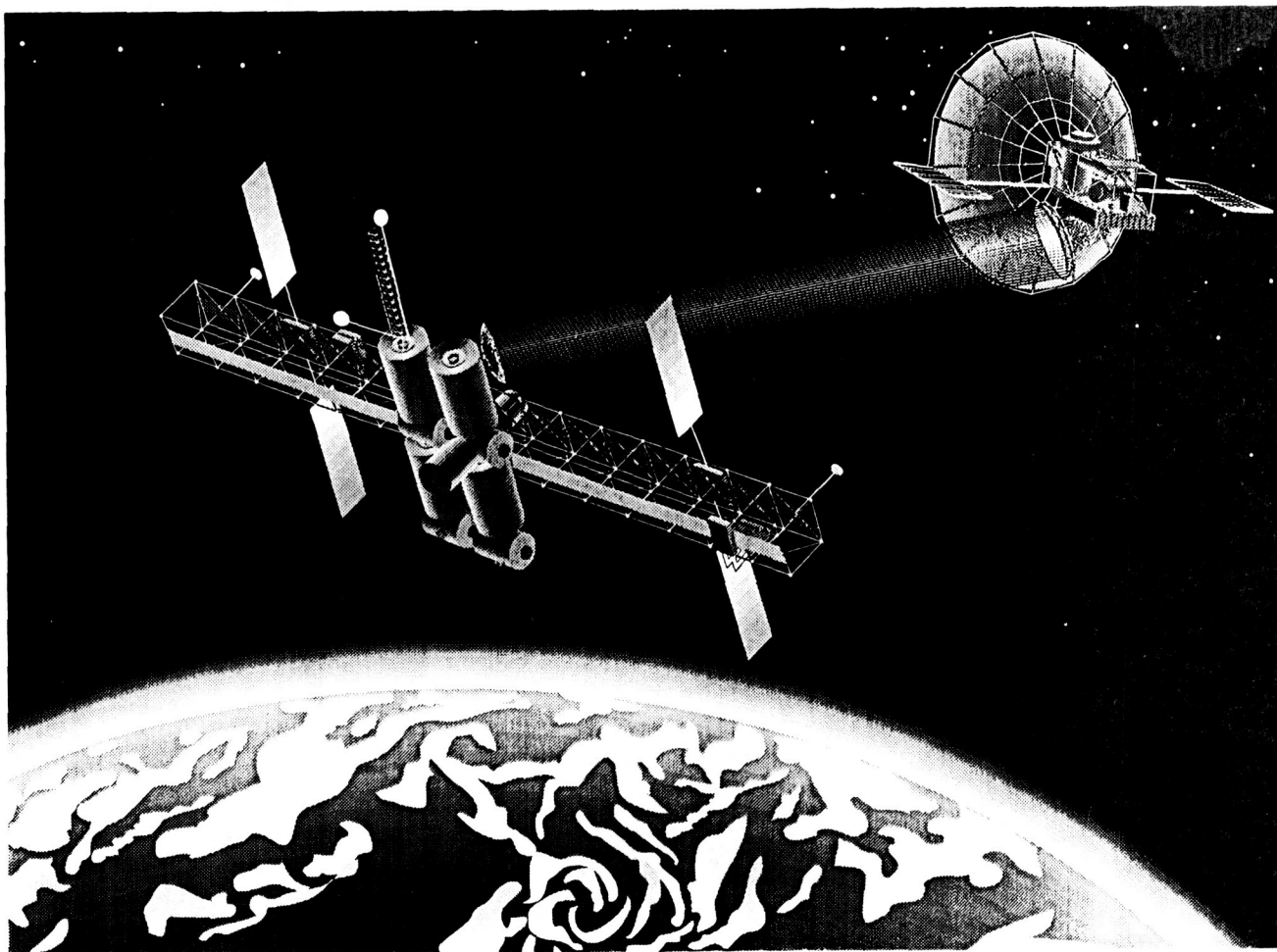
LASER-POWER APPLICATIONS

This figure shows three areas of application. One is a lunar base and we won't discuss that any further. The second application is a space industrial complex which might be in low-Earth orbit or in geostationary orbit. The third application is power beamed from Earth to a spacecraft, (probably a communications satellite) in geostationary orbit. The idea is to use the relatively cheap electrical power on Earth so that a spacecraft in geostationary orbit (therefore always in view) need not carry solar arrays, batteries, etc. We will discuss power beamed from Earth to GEO in our workshop presentations but will not go into powering a space industrial complex, since that is more likely to be an industry than a NASA project.



PRELIMINARY CONCEPT STUDY OF SOLAR-PUMPED LASER POWER BEAMED TO SPACE STATION FREEDOM

This figure shows a laser-power station in high-Earth orbit beaming power to a power relay satellite which is co-orbiting with the Space Station Freedom. The power is re-transmitted from the power relay satellite to the Space Station Freedom providing the power needed there. The advantage of this concept is that drag induced by the large solar arrays can be avoided, since solar photovoltaic power need not be carried on Space Station Freedom. This reduction in frontal area (removal of the solar arrays) not only reduces the drag, it reduces the mass of the Space Station Freedom, as well. Combined, this reduces the number of reboosts necessary to keep the Space Station Freedom in orbit over a long period of time. This concept will be discussed from slightly different points of view in the near-Earth workshop.

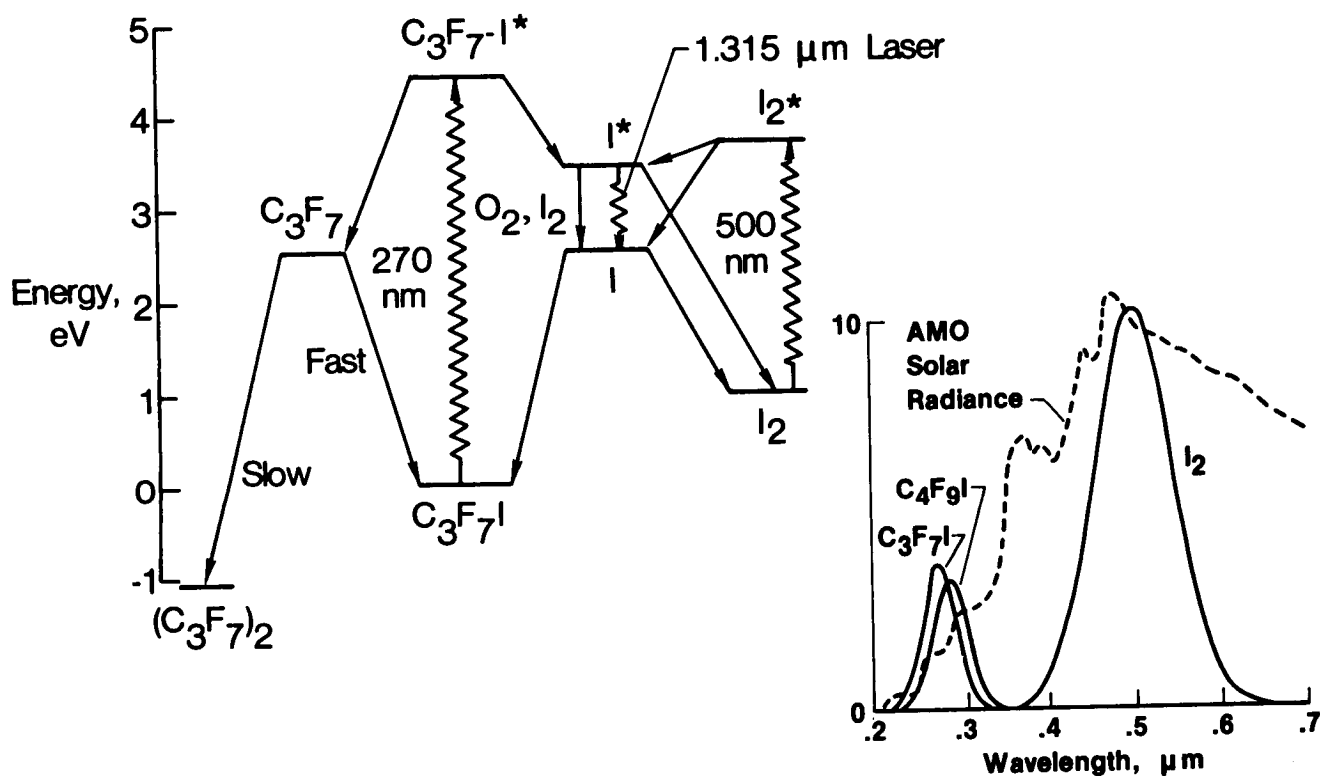


LASERS IN THE MINIWORKSHOP STUDIES

In this session, we discussed the solar-pumped iodine laser, the optically pumped neodymium ion laser, and the electrically pumped diode lasers.

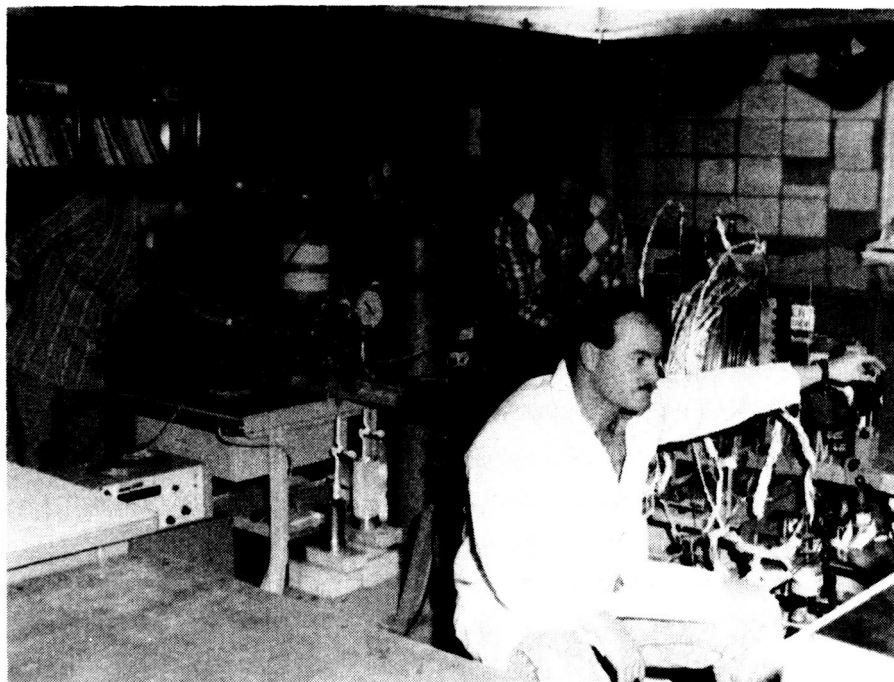
IODINE PHOTODISSOCIATION LASER

This figure shows (1) the absorption spectrum of two iodide lasants superimposed on the air mass zero solar spectrum and (2) an energy level diagram for the lasing process. The iodides absorb at wavelengths less than 300 nanometers, so they are absorbing in a region where the solar radiance is not very strong. The energy diagram for C_3F_7I shows this lasant absorbing radiation at 270 nanometers, being excited to $C_3F_7I^*$, dissociating into I^* and the C_3F_7 radical. The I^* then lases and ultimately recombines into C_3F_7I . A very small fraction of the iodine becomes molecular iodine I_2 , and a very small fraction of the C_3F_7 radical dimerizes to become $(C_3F_7)_2$.



EXPERIMENTAL SOLAR-PUMPED LASER

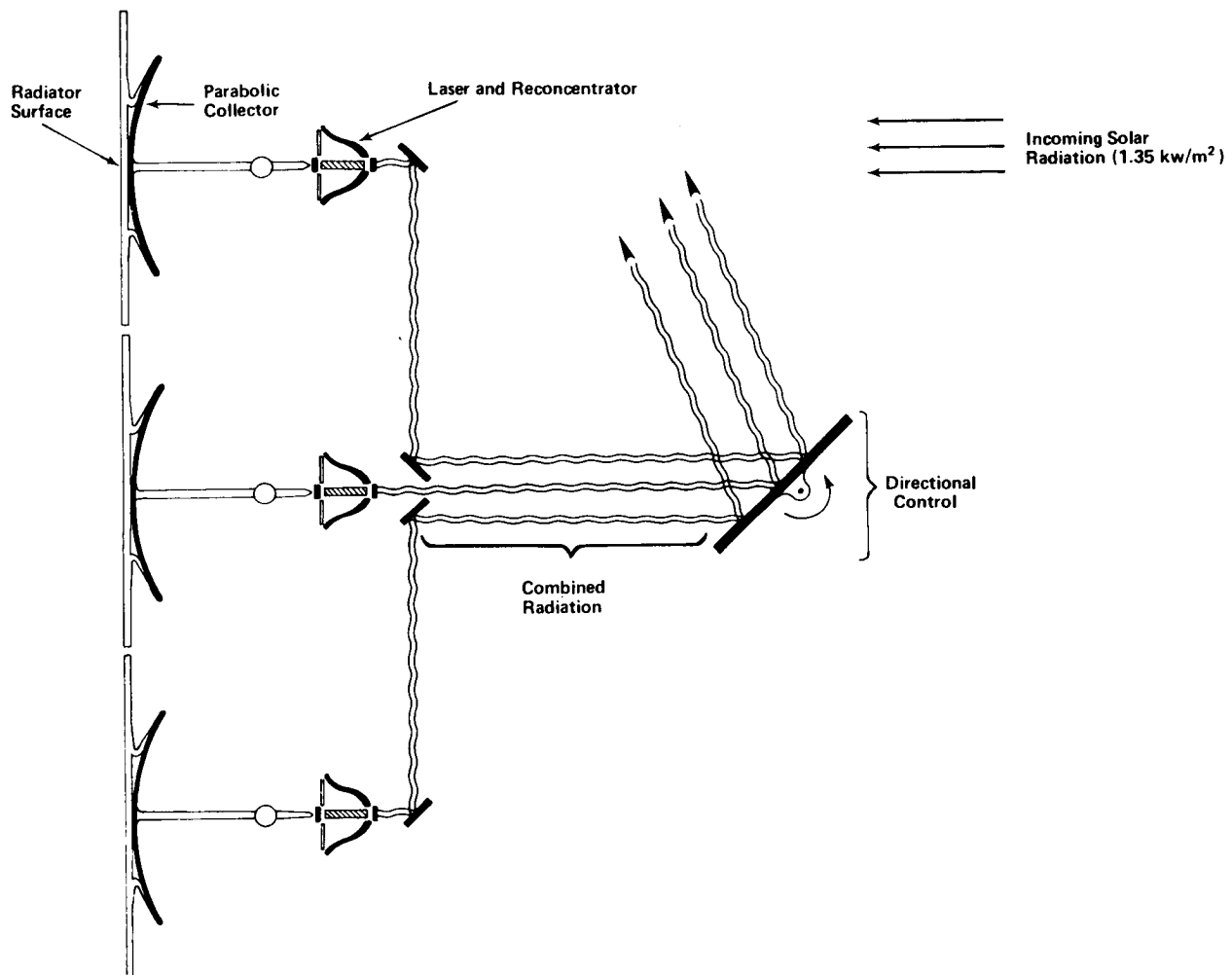
This figure shows several people working on a solar-pumped laser experiment in our lab. A large solar-simulating arc lamp is encased in an elliptical concentrator (beneath the aluminum foil on the right side of the figure). The laser is at one focus of this ellipse and the arc lamp is at the other. Radiation from the laser is emitted toward the left. Experimenters there are involved in adjusting some of the measuring instruments for characterizing the radiation while a technician in the foreground is adjusting the flow rate of the lasant through the laser.



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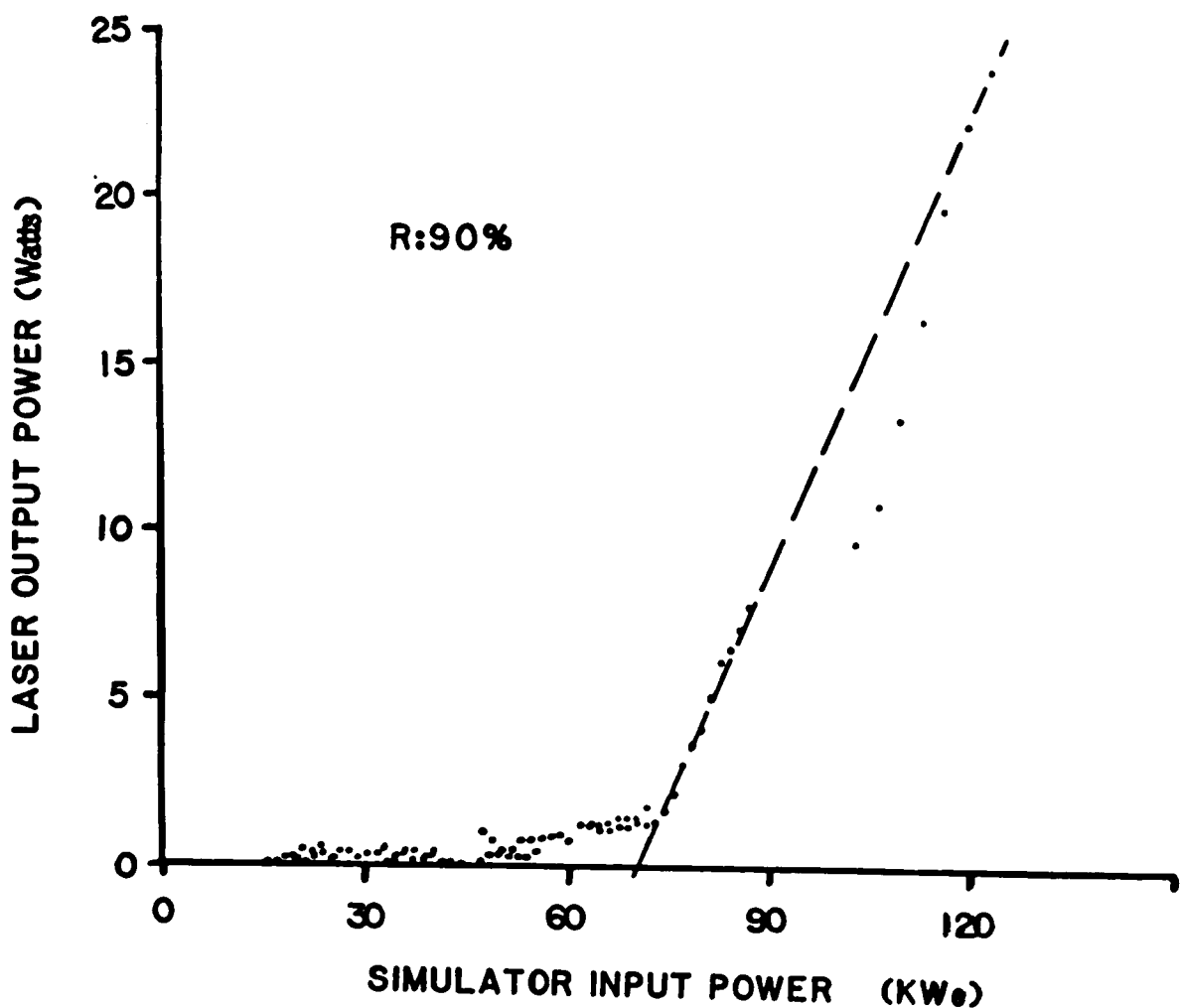
NEODYMIUM THREE PLUS SPACE-BASED LIQUID LASER

This concept shows a large parabolic collector capturing sunlight and concentrating it with a complex concentrator. The second element of this concentrator is called a reconcentrator. The concentrated solar power is focused onto a small laser. The Nd:POCl₃ lasant is being circulated to provide cooling and to remove the hot lasant from the cavity. The 10-megawatt coherent CW beam is emitted from this laser and is transmitted by a reflecting mirror shown on the right side of the figure. The back of the parabolic concentrator is a large radiator with approximately 4×10^5 meters of radiating area.



THE FIBER BUNDLE NEODYMIUM GLASS LASER

One of the reasons that glass lasers are not generally used for solar pumping is that glass has a tendency to fracture where sharp temperature gradients exist. In an attempt to avoid this problem, we have done some experimental laser research with neodymium fibers in a bundle. Water flows through the fiber bundle along the axis to provide cooling. The figure shows laser output power in watts as a function of the simulator input power for a mirror with 90 percent reflectivity acting as the transmitting mirror. This laser, as you can see, produces about 23 or 24 watts.



DIODE ARRAY EXPERIMENT

In this figure we see a researcher adjusting one of the mirrors in an experiment to measure the coherence that can be established between several independent diodes. This experiment tests techniques to gang diodes into arrays which provide large amounts of coherent power.



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SUMMARY

In ~~this presentation, we reviewed~~ the concepts of laser power-beaming applicable to advanced NASA missions. ~~This review covered many concepts not developed for this workshop, and it was intended to give you a broader view of what is possible.~~ We ~~identified some specific concepts to be presented at the miniworkshops, and we've briefly discussed~~ the types of lasers (the iodine lasers and the diode lasers) which are central to the laser miniworkshop presentations *are discussed.*